Gravity Probe - B: Reviews and Current Status

SEUS Meeting at NASA HQ

July 2, 2003

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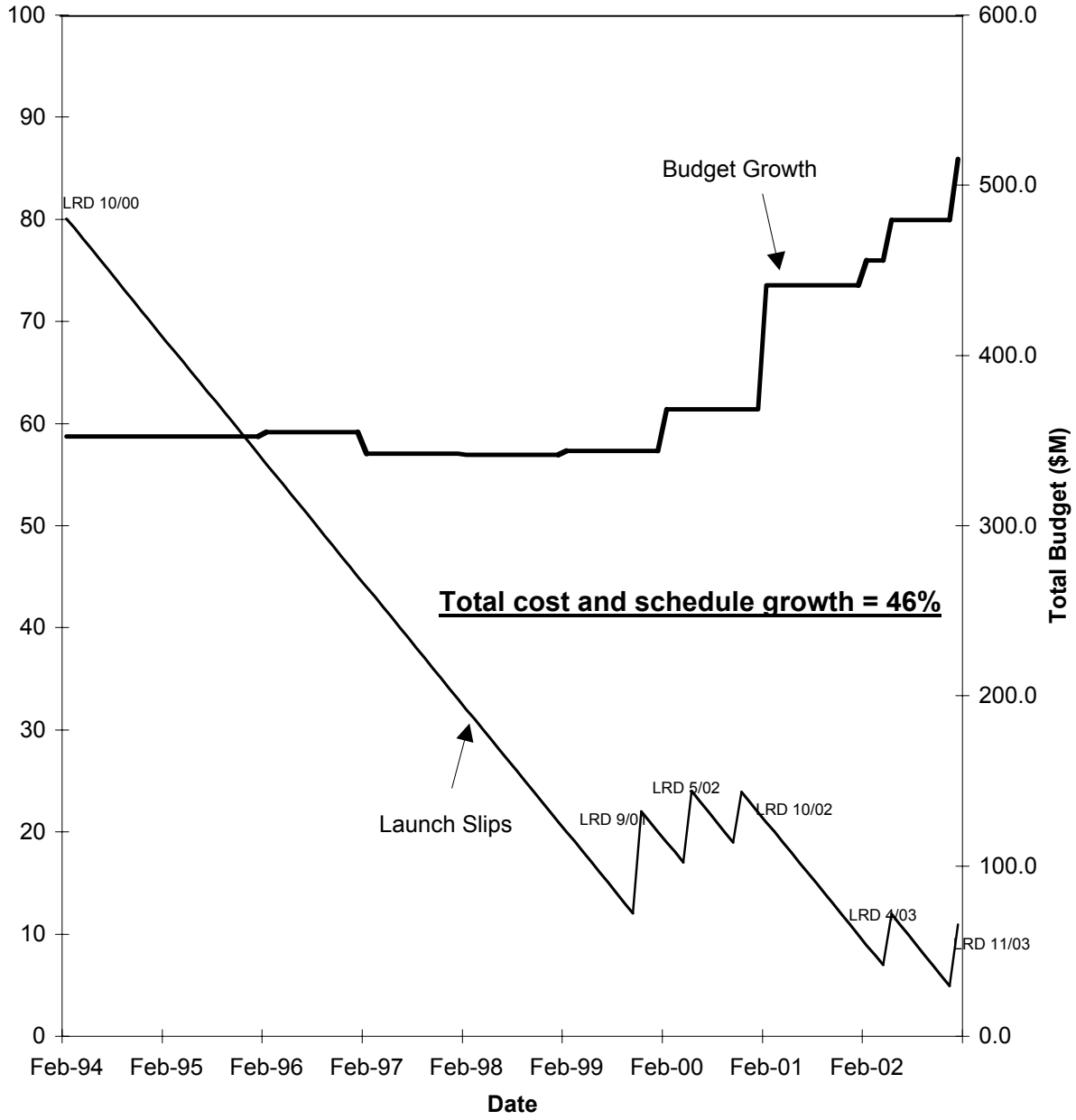
History of GP-B Problems

- Past history of problems
  - 1998 - Design problem with method used to fasten probe to dewar
  - 1999 - Heat transfer problem on probe and open circuit in one gyro required removal of probe from dewar for repair. As a result of these problems and concerns about gyro system parts qualification, NASA required addition of a separate payload acoustic test.
  - 2001 - Nitrogen bottle accidentally connected to helium dewar
  - 2001 - Tests of electronics revealed design changes required - delayed completion of electronics
  - 2002 - Planned cable integration schedule inadequate - additional ground support equipment had to be designed and built
  - 2002 - Leak in helium vent line required redesign of line and repair
  - 2002 - Series of problems encountered during thermal vacuum testing
    - Electronic box failures
    - Chamber helium leak - inability to maintain cold temperature profile
    - Evacuation of residual gas in probe not done prior to test led to higher dewar boil-off rate

GP-B History


100
90
80
70
60
50
40
30
20
10
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600.0
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Total Budget ($M)
LRD 10/00
Budget Growth
Total cost and schedule growth = 46%
Launch Slips
LRD 9/01
LRD 5/02
LRD 10/02
LRD 4/03
LRD 11/03
Feb-94
Feb-95
Feb-96
Feb-97
Feb-98
Feb-99
Feb-00
Feb-01
Feb-02
Date

Gravity Probe-B
History of Schedule Delays and Cost Growth

Original baseline: February 1994. GP-B budget flattened at $50M/year

- Stanford targeted launch for 12/99
- Official LRD (with 10 months of additional reserve) became 10/00
- Spacecraft cost ~$353M

Replan #1: November 1999	LRD 9/01	cost ~$368M (+$15M)
Replan #2: May 2000	LRD 5/02	cost ~$441M (+$73M)
Replan #3: November 2000	LRD 10/02	cost ~$456M (+$15M)
Replan #4: May 2002	LRD 4/03	cost ~$480M (+$24M)
Replan #5: January 2003	LRD 11/03	cost ~$519M (+$39M)

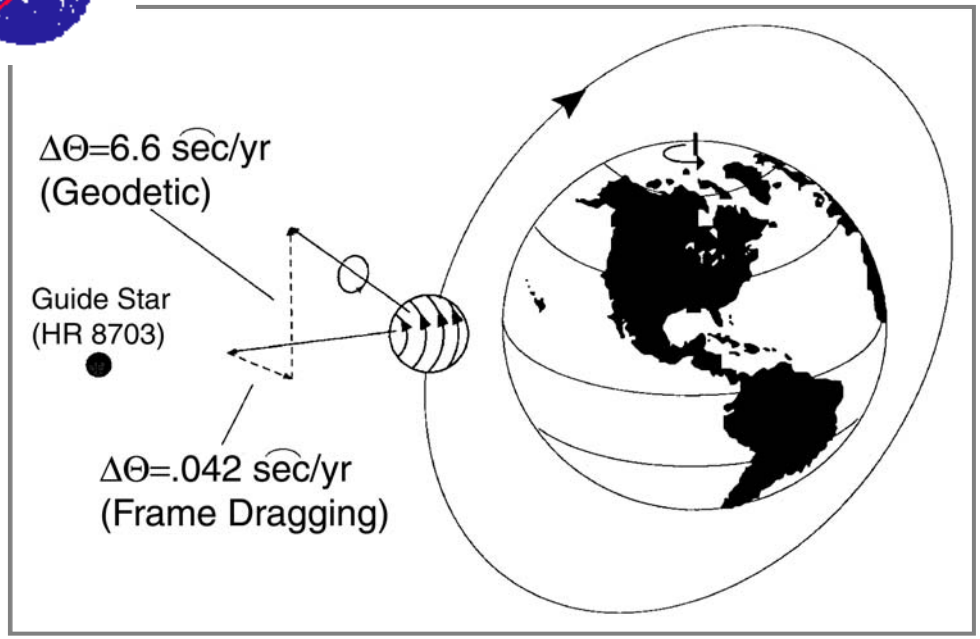
In the last 39 months: five replans

- **37 months of delay vs. original schedule**
- **Spacecraft budget increased ~$166M**

26 Feb 2003 EPMC Meeting

- MSFC proposed replan which moved launch date from April 2003 to November 20 2003
- Cost increase associated with Launch Slip $39M
- Replan not approved
  - Project permitted to proceed to a launch date no later than November 20, 2003
  - Science and Technical/Risk of GP-B to be evaluated by two Independent Panels

GP-B Science Goals



GP-B	Original Level 1	New, post-T/V
Precession rate error	<0.5 marc-s/y	0.038 marc-s/y

Does not include guide star error

GP-B measurement accuracies	Original Level 1 accuracy (GP-B)	New, post T/V accuracy (GP-B)	Current experimental accuracy (in γ)
Geodetic precession	7.5×10^{-5}	0.6×10^{-5}	2×10^{-3} (Viking) 2×10^{-5} (Cassini)
Frame dragging	1.2%	0.1%	20% (direct) 0.1% (indirect)

GP-B Science Review Panel

- Michael Turner (Chicago), Chair
- David Gross (KITP, U.C. Santa Barbara)
- James Hartle (U.C. Santa Barbara)
- John Mather (NASA/GSFC)
- Kip Thorne (Caltech)
- Rainer Weiss (MIT)
- Clifford Will (Washington U.; also Chair of GP-B Science Advisory Committee)

Panel Timeline

10 March 2003: Panel formation

30-31 March 2003: Panel meeting in Pasadena, CA

13 April 2003: Panel telecon to finalize report

21 April 2003: Submission of final report to Anne Kinney

Science Panel Charge and Response

- *Has there been erosion in the scientific importance of GP-B's primary science goals over the last decade?*
  - "…(1) there has been some erosion in the scientific value of GP-B's frame-dragging measurement and
  - (2) there has been more significant erosion in the scientific value of GP-B's measurement of γ."
  - "Evidence for the frame-dragging effect has been presented … in the precession of the LAGEOS satellites (estimated error of 20%)…"
  - "A host of experimental tests of gravity in the solar system has constrained the possibilities for a viable theory of gravitation to such a degree that no concrete metric theory is currently known that is in agreement with all current experiments and yet predicts a frame-dragging effect in GP-B that differs from GR by more than the nominal GP-B accuracy."
- *The panel is requested to place the science potential of GP-B in the broader context of SEU missions of comparable cost magnitude.*
  - "The potential of LISA to extend our understanding of gravity far exceeds that of GP-B, although it is not expected to provide a quantitative test of frame-dragging.

Science Panel majority is supportive of GP-B

- "Direct measurement of the Lense-Thirring effect will be a triumph comparable to the first measurements of the bending of starlight by the sun and will rank as a textbook result for decades."
- "No other laboratory or space experiment, current or near term, has the capability to measure this effect [inertial frame dragging] to comparable precision."
- "GP-B is still a precedent-breaking mission for the space program in that it will perform a precision physics experiment in space. It will leave a new heritage for space research…"

GP-B Technical/Risk Review Panel

Tom Fraschetti	Chair
Don Shick	Deputy Chair (IPAO)
Larry Baugher	S&MA
Steve Castles	Cryogenics, Flight Instruments
Michelle Calloway	Resources
Kimberly Hawkins	Software
Michael Lembeck	Systems/Project Management
Mark Lysek	Cryogenics/Thermal Analysis
Luis Morales	Mission Operations
Anita Thomas	Schedule Analysis
Frank Volpe	Systems Engineering
Roger Williamson	Flight Electronics

Technical/Risk Panel Findings

- Low confidence that GP-B will meet a launch readiness date of November 2003
  - Project Response: Project has not slipped schedule since January 2003 and holds 71 days of reserve to a November 20 launch date
- High confidence in achieving Mission Success after launch provided:
  - Successful resolution of current hardware issues
  - Penalty TV test conducted with 2 full cycles
  - 200 hours of error-free Space Vehicle operation should be completed
  - Mission Operations readiness receives appropriate attention
  - Project Response: Project essentially concurred with the above comments, and has implemented changes consistent with those comments. The Project incorporated a second TV cycle into its plans at the request of Code S, even though the Project did not feel it was necessary

Technical/Risk Panel Findings (cont'd)

- GP-B was originally set up as a "management experiment" with limited MSFC oversight. The "management experiment" is over and MSFC now provides more traditional levels of oversight, but the risk remains inherently higher than other missions of comparable cost. Mitigations applied now cannot fully address the risks incurred during the "management experiment."
  - Project Response: There are no accepted "high" risks at this time

30 April 2003 EPMC Meeting

- Technical/Risk Panel and Science Panel Reported their findings
- MSFC Project Manager responded to the Technical/Risk Panel
- Stanford PI Responded to the Science Panel Findings (measurement accuracy improved by order of magnitude --> still cutting edge science)
- Astronomy & Physics Division Recommended Cancellation of Mission based on diminished scientific value of GP-B and low confidence in reaching November launch.

30 April 2003 EPMC Meeting (cont'd)

- Decision by EPMC
  - GP-B allowed to continue but must pass two "Gates" and adhere to schedule which permits launch no later than Nov 20, 2003. Gates:
    - Successful TV Test
    - Successful Ops Preparation

Thermal Vacuum Success Criteria

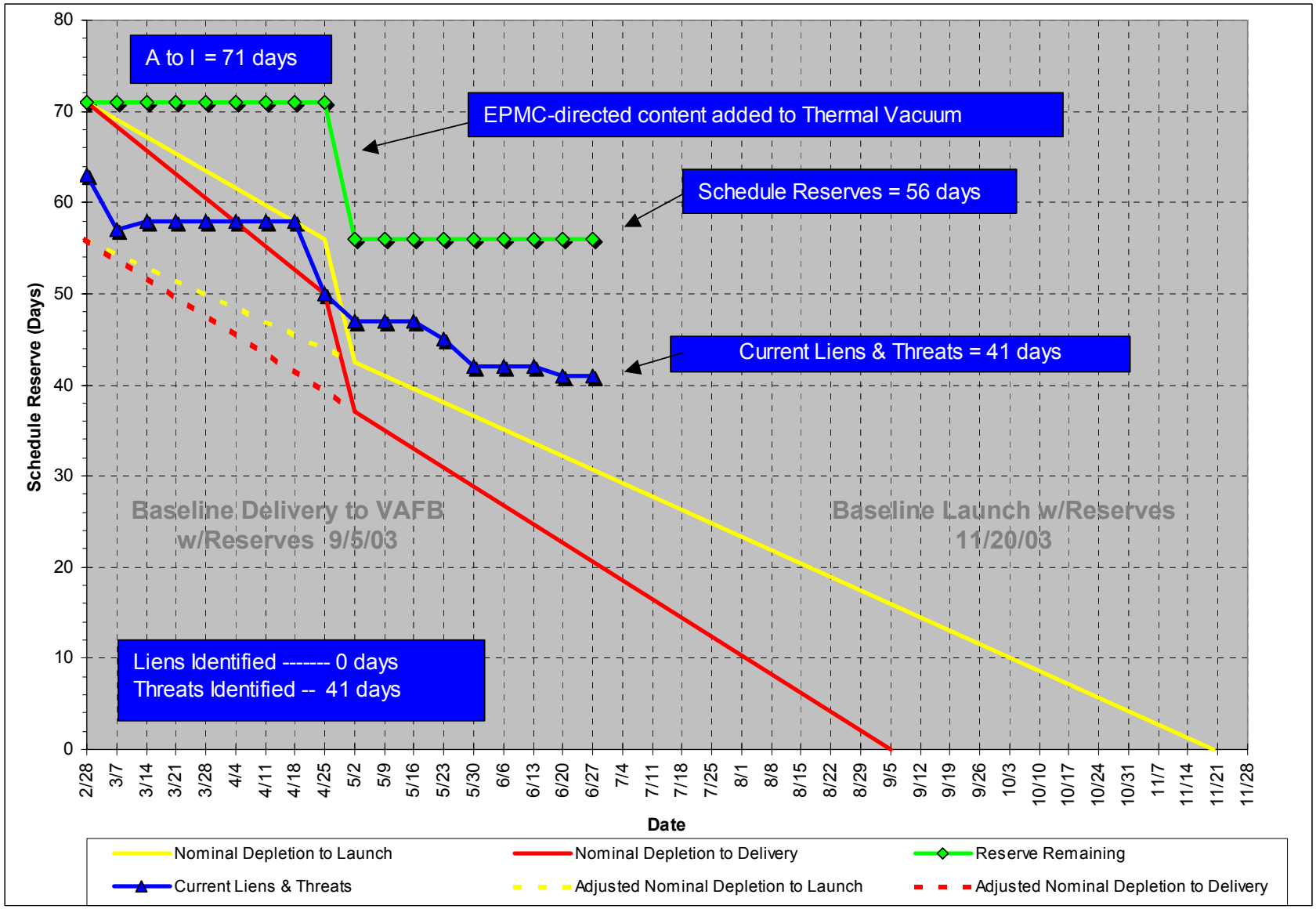
- Results consistent with meeting Level 1 Requirements (e.g. He boil-off rate)
- No Systems Level Thermal Vacuum re-test will be required
- Thermal Vacuum results must be independently verified by MSFC and the GP-B IRT
- Thermal Vacuum results will be reviewed plus
  - Review of all Risks
  - Status of all single point failures and mitigation plans
  - Status of Launch Critical items
  - All other normal MRR topics

Mission Ops Success Criteria

- Successful completion of SIM 5
- Successful completion of SIM 6
- All High and most Medium Risk contingencies must be completed by FOR
- All procedures for IOC completed, tested, and verified by FOR
- Operator training plan must be presented
- Must have accumulated at least 200 hours of integrated operations time on the Space Vehicle with the Ops team.
- Mission Ops will be independently verified

Schedule Reserve / Liens & Threats Status

(as of 06/27/03)



GP-B Status

- TV test completed
  - Success determination to be made by IRT in series of reviews ending in Mid July
    - Data Review from Penalty TV Completed
    - Close out of all technical issues by Pre-Ship Review (July 1)
    - Decision of "success" of TV test to be made mid July
- Ops Preparation
  - Success determination to be made by Independent Panel
    - Mission Sim #5 completed
    - Decision of "success" of Mission Ops preparation to be made mid August
- Project holding ship date of July 10 to VAFB which permits launch by Nov 20 with slack.